

Extremity compartment syndrome: What you need to know

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ABSTRACT:

Acute compartment syndrome of the extremities represents one of the few true orthopedic surgical emergencies, and early surgical fasciotomy is the only effective treatment. Ironically, the classic guidance emphasizing the clinical “6 P’s” for establishing the diagnosis (pain, pallor, poikilothermia, pulselessness, paresthesia, paralysis) is inherently misleading, since pain out of proportion, refractory to analgesics, often represents the sole clinical indicator of an evolving acute compartment syndrome. The remaining “5 P” symptoms generally indicate a late or missed compartment syndrome, which is associated with preventable adverse patient outcomes and a risk for nondefensible litigation. The science on this topic is compromised by the absence of a defined diagnosis, which remains predicated by the treatment modality of whether a fasciotomy was performed or not. The current “What you need to know” article was designed to unveil enigmatic myths, misconceptions, and controversies around the conundrum of acute extremity compartment syndrome, based on the current available evidence in the field. Evidence-based recommendations include the recently updated 2025 Clinical Practice Guideline by the American Academy of Orthopaedic Surgeons (AAOS), the American College of Surgeons’ TQIP best practice guidelines, and published consensus recommendations from the British Orthopaedic Association and the Association of Anesthetists of Great Britain. The intent of this narrative review is to provide the general surgeon with clinically relevant tips and tricks and to deliver pragmatic decision-making strategies with the ultimate goal of improving patient safety and clinical outcomes. (*J Trauma Acute Care Surg.* 2026; 00:000–000 Copyright © 2026 Wolters Kluwer Health, LLC. All rights reserved.)

KEY WORDS:

Acute compartment syndrome, extremity, fasciotomy, pain out of proportion, intracompartmental pressure.

Acute compartment syndrome of the extremities represents one of the few true orthopedic surgical emergencies.¹ A high level of suspicion for an evolving compartment syndrome is essential and should be based on the patient’s history and physical examination, even in the absence of an underlying trauma mechanism.^{2,3} The skeletal muscle compartments of the extremities are enclosed by relatively noncompliant osteofascial boundaries with limited capacity to accommodate increases in intracompartmental volume.⁴ As emergent surgical fasciotomies offer the only effective treatment, the current review article was designed to unveil frequent unjustified assumptions that continue to jeopardize patient safety by delayed recognition and timely appropriate surgical treatment of acute extremity compartment syndrome.

PATHOPHYSIOLOGY

Any pathophysiologic process that results in increased pressure within a closed osteofascial compartment

of the extremity has the potential to evolve into acute compartment syndrome, independent of presence or absence of an underlying trauma mechanism or an associated fracture.^{5,6} A normal intracompartmental tissue pressure ranges between 0 and 8 mm Hg.⁷ Rising intracompartmental pressure initially impairs venous outflow because veins are thin-walled and easily compressed, reducing the arteriovenous pressure gradient and progressively compromising capillary perfusion.⁸ The resulting tissue ischemia increases endothelial permeability and interstitial edema, creating a self-perpetuating cycle of rising compartment pressure and worsening tissue perfusion.^{5,6,8} Arterial inflow is typically maintained until late in the disease process; therefore, palpable distal pulses do not exclude acute compartment syndrome.^{5,6,8} Irreversible tissue ischemia will develop when intracompartmental pressure approximates the patient’s diastolic blood pressure, with a critical threshold for acute compartment syndrome considered by a perfusion gradient of < 30 mm Hg.⁹ Persistent ischemia initiates a vicious inflammatory cycle characterized by release of pro-inflammatory cytokines, free radicals, and complement activation.¹⁰ This inflammatory cascade induces endothelial injury, increased vascular permeability, interstitial edema, and further exacerbates intracompartmental pressure, ultimately leading to cellular hypoxia and irreversible muscle and nerve necrosis (Fig. 1).

Although frequently associated with acute trauma, compartment syndrome of the extremities can evolve from a variety of atypical causes listed in Table 1. Although rare, acute extremity compartment syndrome has been described in low-energy trauma mechanisms,^{33,34} and idiopathic compartment syndrome has been reported

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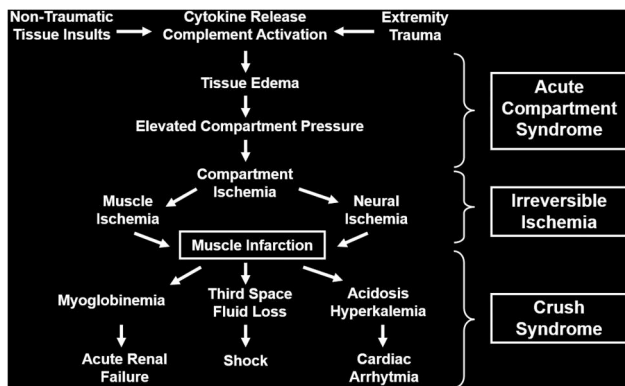


Figure 1. Schematic of the vicious cycle of acute compartment syndrome leading to inflammation and cellular edema with subsequent delayed neuronal and muscular ischemia and ultimately irreversible intracompartmental cell death. See text for details and explanations.

in the absence of any identifiable precipitating events.^{2,3} This observation underscores the importance of maintaining a high level of suspicion and clinical vigilance in the differential diagnosis of patients presenting with acute and severe extremity pain, regardless of the underlying etiology.³⁵

THE MYTH OF AN 'EVOLVING' COMPARTMENT SYNDROME

Acute extremity compartment syndrome represents a “can’t miss diagnosis” due to the irreversible adverse sequelae of a delayed or missed diagnosis.^{7,36} Selected fracture patterns warrant a heightened suspicion for an evolving extremity compartment syndrome, including high-energy tibial fractures (proximal or diaphyseal) in the lower extremity (Fig. 2), and both-bone forearm fractures in the upper extremity (Fig. 3). The primary diagnostic challenge is that an evolving (or impending) compartment syndrome is often subclinical and oligosymptomatic, particularly in the presence of distracting injuries or in obtunded patients.³⁷ No laboratory or imaging modality has been validated for the early diagnosis of extremity compartment syndrome.⁴⁻⁶ Serial clinical examination (at least every hour) remains the cornerstone of diagnosis in the case of equivocal clinical symptoms.⁴⁻⁶ Progressive deterioration on serial examination with increasing pain on passive stretch and worsening compartment tension should be viewed as evidence of an evolving compartment syndrome.⁴⁻⁶ This should prompt prompt emergent surgical decompression rather than continued observation.⁷ Accordingly, the most important diagnostic tool remains a high level of clinical suspicion in any patient with acute extremity pain, also in the absence of a trauma mechanism or an associated fracture.³⁶ Even minor events, such as extravasation of a peripheral in-

travenous line in the upper extremity can lead to an acute iatrogenic compartment syndrome.¹³ In the awake patient, the hallmark symptom is pain out of proportion to the injury, often refractory to analgesics.³⁵ Pain with passive stretch of the involved muscle compartment is another important early clinical finding to confirm the diagnosis. Common causes of a delayed or missed extremity compartment syndrome include: (1) not considering the differential diagnosis in absence of a trauma mechanism; (2) reliance on late clinical, laboratory, or imaging manifestations of tissue ischemia; (3) lack of a surgeon’s clinical experience, or hesitation by junior providers (residents or advanced practice providers) to escalate the concern to senior staff; (4) hesitation to perform fasciotomy in patients with early evolving compartment syndrome; (5) performing incomplete fasciotomies with missed compartments under pressure. This concept is illustrated by the first author’s experience over more than two decades of orthopedic trauma practice: “In my entire career, I have never been called for an evolving compartment syndrome. I have invariably been consulted on patients with late or missed compartment syndromes.” (P.F. Stahel, unpublished observations).

Conversely, indiscriminate fasciotomy in patients with equivocal findings may expose patients to unnecessary surgery³⁸ with prolonged hospitalization, risk of infection, wound complications, and long-term disability. However, when a clinical suspicion exists, the morbidity of a potentially unnecessary fasciotomy is generally outweighed by the irreversible consequences of a late/missed compartment syndrome.³⁶ In the absence of a definitive diagnostic standard, surgical fasciotomy has become a surrogate for the diagnosis of acute compartment syndrome, by substituting treatment for diagnostic certainty.³⁹ This notion is particularly relevant in patients with impending (or evolving) compartment syndrome, in whom prophylactic fasciotomy may be performed in the face of diagnostic uncertainty.³⁹ Fear of medicolegal consequences may further lower the threshold for a surgical intervention.⁴⁰ Ultimately, the diagnosis of extremity compartment syndrome relies on the surgeon’s clinical judgment and decision-making.

THE HISTORIC 6 P’S REVISITED

Traditional teaching emphasizes the classic 6 P’s as clinical symptoms indicative of an evolving compartment syndrome, as outlined below.²²

1. **Pain** (subjective pain from pressure and ischemic tissue injury)
2. **Pallor** (paleness of the skin from hypoperfusion)
3. **Poikilothermia** (hypothermia from reduced circulation)
4. **Pulselessness** (vascular compromise from elevated pressure)
5. **Paresthesia** (early nerve damage from elevated pressure)
6. **Paralysis** (end-stage nerve damage from continued pressure)

TABLE 1. Atypical Causes of Acute Extremity Compartment Syndrome

Acute exertional compartment syndrome ¹¹
Postoperative compartment syndrome after extremity fracture fixation ¹²
Intravenous fluid or contrast dye extravasation ^{13,14}
Constricting bandages or cast immobilization ^{15,16}
Tourniquet or blood pressure cuff-related compartment syndrome ^{17,18}
Well-leg postoperative compartment syndrome in (hemi-) lithotomy position ^{19,20}
Fluid extravasation during arthroscopy ²¹
Revascularization with ischemia-reperfusion syndrome ^{22,23}
Systemic inflammatory response syndrome/massive fluid resuscitation ²⁴
Soft tissue infections ²⁵
Burn injuries ^{26,27}
Snake bites ²⁸
High-pressure injection injuries ²⁹
Nephrotic syndrome ³⁰
Anticoagulation and spontaneous hemorrhage ³¹
Intracompartmental malignant process ³²

Aside from a patient's subjective pain out of proportion (P #1), as a surrogate of evolving compartment syndrome, the remaining five P's are actually reflective of a late or missed compartment syndrome.³⁶ These five P's typically pertain to impaired vascular perfusion and/or nerve damage from continued intracompartmental pressure. By the authors' strong personal opinion (and as a compelling teaching point to younger surgeons), the historic paradigm of the 6 P's as clinical indicators of an evolving acute compartment syndrome should be provocatively revised, as such:

1. Pain out of proportion
2. Pain out of proportion
3. Pain out of proportion
4. Pain out of proportion
5. Pain out of proportion
6. Pain out of proportion

The term "pain out of proportion" entails subjective pain that may initially be well controlled and will subsequently escalate to an intolerable point in spite of the administration of increasing doses of analgesics.³⁵ Additional clinical signs include tight muscle compartments that are tender on palpation and exacerbated pain by passive stretch of the muscle compartments, for example, by passive dorsiflexion of the greater toe and ankle, to increase the extent of subjective pain beyond a patient's pain level at rest.³⁵

WHEN TO MEASURE COMPARTMENT PRESSURES?

As discussed above, acute extremity compartment syndrome represents an exclusive clinical diagnosis in the awake patient. Of note, measuring compartment pressures is not required for establishing either the diagnosis or the indication for emergent fasciotomies.^{4,39} Thus, the measurement of intracompartmental pressures should be reserved to selected limited indications:

1. Obtunded patients or patients with otherwise unreliable or unobtainable clinical examination.
2. Documentation of normal compartment pressures in awake patients with equivocal examination or subclinical symptoms, to avoid potentially unnecessary fasciotomies.
3. Any equivocal scenario (eg, questionable history, absence of a trauma mechanism, regional anesthesia, etc) with the intent to rule out the presence of an acute compartment syndrome.

Intracompartmental pressures are obtained by a direct measurement technique. This is typically done through a conventional hand-held manometer connected to an 18-gauge needle, commonly known as the "Stryker device" (Stryker Corporation, Portage, MI). The point-of-use technique, depicted in Figure 4, allows for a single time-point or repeat serial compartment pressure measurements. (On a side note, this technical device has received such widespread global recognition that its brand name has become a slang verb in the orthopedic trauma jargon—"to *stryker* a compartment"). Alternatively, continuous pressure monitoring can be performed using a slit catheter technique through a transducer connected to a pressure amplifier and recorder.⁹ The benefits of continuous pressure monitoring over single-point measurements have been emphasized in the recent peer-reviewed literature.^{9,12} For either technique, the clinician must be familiar with the anatomy of the respective extremity compartments. The four compartments of the leg are schematically depicted in Figure 4. Importantly, after surgical prepping of the skin, the tip of the needle must be "zero-ed" at the skin level for accurate calibration before insertion. The needle is then inserted into the targeted compartment at a slight angle to the skin, followed by injection of around 1 mL sterile saline to clear the needle from content of adherent tissue before pressure measurements. In presence of a fracture, the tip of the needle should be placed within about 5 cm of the fracture level to obtain accurate pressure readings. Placing the needle tip

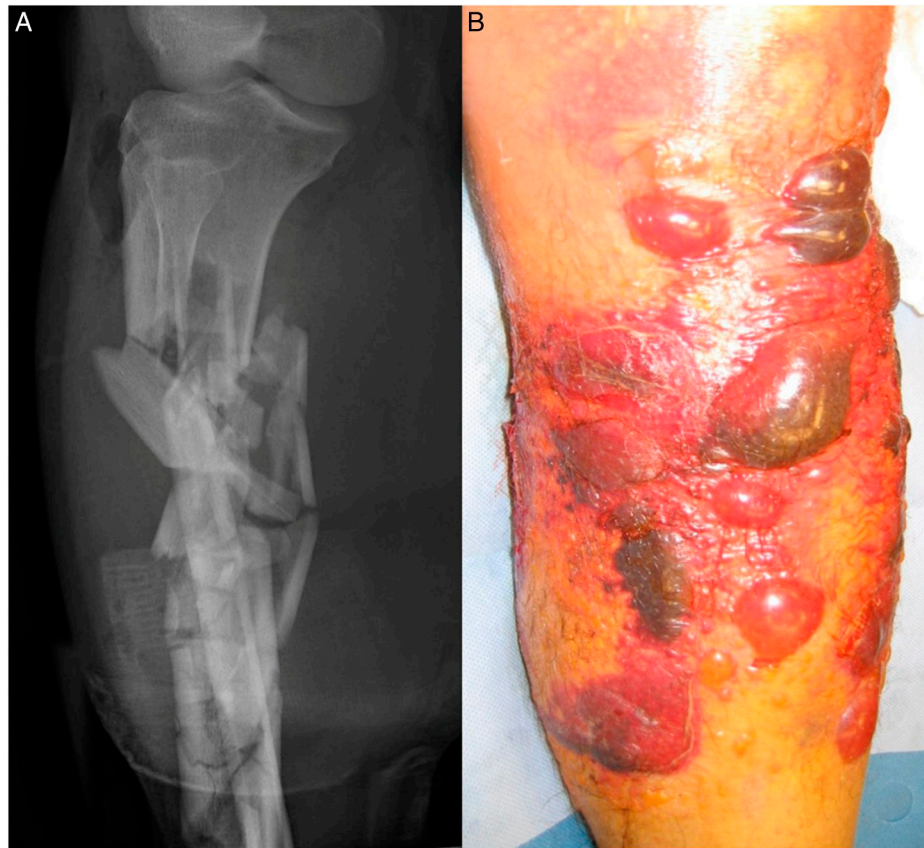


Figure 2. Clinical example of acute lower extremity compartment syndrome. High-energy comminuted segmental tibial shaft fracture (A) with associated acute compartment syndrome and soft tissue “fracture blisters” (B).

in closer proximity to the fracture may lead to false negative readings when engaging with the fracture hematoma. Recently, ultrasonography and other noninvasive monitoring techniques have been proposed as alternative options for serial examination of extremity compartments; however, these modalities have not been formally validated for clinical adoption with diagnostic accuracy.^{41,42}

WHEN TO CUT?

The clinical suspicion of an acute extremity compartment syndrome justifies the emergent (absolute) indication for early decompressive fasciotomies, independent of the injury severity, and also in absence of an underlying trauma mechanism.⁴³ The presence of an open fracture does not preclude from development of acute compartment syndrome,⁴⁴ as traumatic fascial tears are typically incomplete and confined to the level of the open fracture, whereas “nondecompressed” musculature remains at risk. Further, even after surgical débridement and internal fracture fixation, wound closure can still lead

to a postoperative compartment syndrome, as illustrated by the complication shown in Figure 3.

As already discussed, compartment pressure measurements are not required for the diagnosis or decision to take a patient to the operating room for early decompressive fasciotomies. The American College of Surgeons’ Trauma Quality Improvement Program (ACS-TQIP) guidelines⁴⁵ provide pragmatic indications for early fasciotomies:

- Any awake patient with clinically suspected acute compartment syndrome of the extremities.
- Clinical suspicion includes pain out of proportion, pain with passive stretch of the musculature in the involved compartment, and paresthesia of the nerve(s) within the respective compartment.
- Absence of these clinical symptoms is reliable in ruling out acute compartment syndrome at the time of the examination.
- Sequential physical examinations are recommended for any patient at risk of developing acute compartment syndrome of the extremities.
- Intracompartmental pressures should be obtained in patients with unreliable or unobtainable clinical examination (eg, obtunded patients).

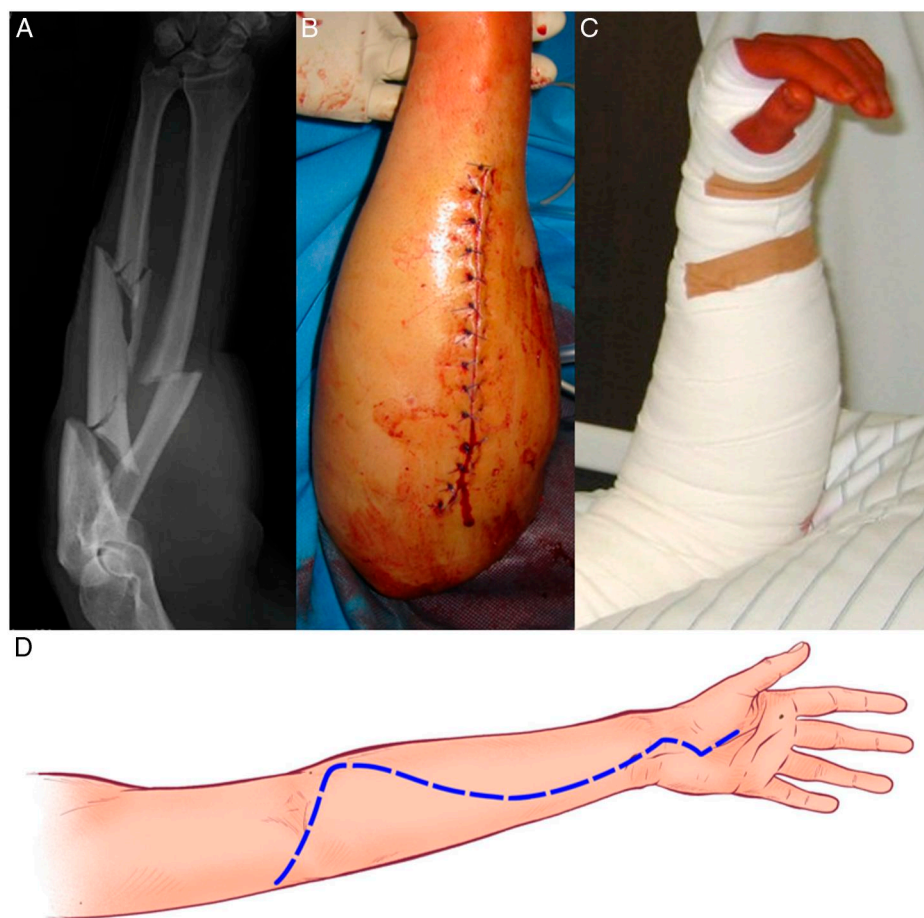


Figure 3. Clinical example of a missed upper extremity compartment syndrome. High-energy segmental both-bone forearm fracture (A) managed by open reduction with internal fixation (ORIF) on post-injury day 2. The patient developed a missed postoperative compartment syndrome (B) with a “wrist-drop” paralysis from a posterior interosseus nerve palsy (C). He was taken back to the operating room for an emergent forearm compartment release through the pre-existing dorsal surgical incisions. The graphic artwork depicts the authors’ generally preferred volar extensile curvilinear forearm fasciotomy incision line with extension across the wrist for carpal tunnel release (D).

- A gradient <30 mm Hg of diastolic blood pressure minus compartment pressure represents an indication for early fasciotomies.

HOW TO CUT?

Once the surgical indication is placed by clinical signs or pressure gradients, emergent fasciotomies are performed through long and generous skin incisions with complete fascial release of the affected compartments. Minimally invasive or percutaneous fascial release should be reserved to rare selected instances with elective surgical indications, for example, for chronic recurring exertional compartment syndrome.⁴⁶ The main surgical pitfall in the management of acute extremity compartment syndrome is reflected by incomplete compartment release, either (1) by

compromising the size of skin and fascial incisions; (2) by erroneously assuming compartment release in open fractures without decompressing the retained intact fascial elements; or (3) by ignorance about the surgical anatomy of the affected muscle compartments. Any incomplete or unreleased compartment will continue perpetuating the vicious cycle of increasing intracompartmental pressure to the point of irreversible cellular ischemia and tissue necrosis. Figure 5 illustrates the standard four-compartment fasciotomy for acute compartment syndrome of the leg, as exemplified by the traditional dual-incision surgical approach (two upper panels).⁴⁷ For technical aspects, the anterolateral compartment incision of the leg should be between the subcutaneous border of the tibia and the fibular head. The skin incision and fascial release should be full length for release of the anterior and lateral compartments. Care must be taken to avoid injury to the

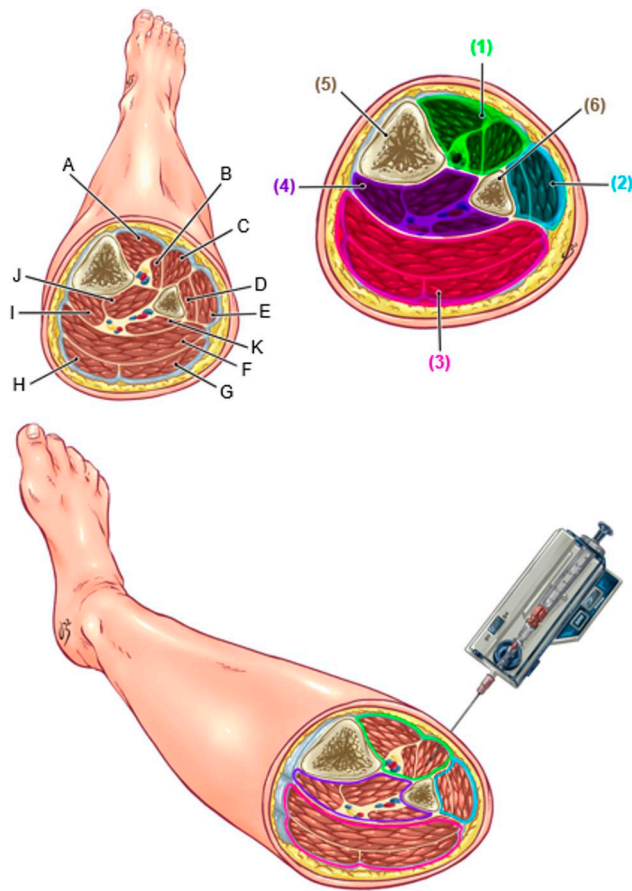


Figure 4. Anatomy of the four compartments of the leg (upper panel). The lower panel depicts an example of point-of-care pressure measurements with the handheld device needle placed inside the anterior compartment. (1) Anterior compartment (green): A, tibialis anterior; B, extensor hallucis longus; C, extensor digitorum longus. (2) Lateral compartment (blue): D, peroneus brevis; E, peroneus longus. (3) Superficial posterior compartment (pink): F, soleus; G, gastrocnemius (lateral head); H, gastrocnemius (medial head). (4) Deep posterior compartment (purple): I, flexor digitorum longus; J, tibialis posterior; K, flexor hallucis longus. (5) Tibia. (6) Fibula.

superficial peroneal nerve in the lateral compartment release (ie, the Metzenbaum scissors should not be “slid” down blindly due to limited-size skin incisions). The lower panel in Figure 5 illustrates the concept of the single lateral incision. Independent of the preferred surgical technique, a complete release of the deep posterior compartment is critical and frequently missed. If the lateral and deep posterior compartments are not released, this oversight will eventually lead to two missed “dead” compartments with associated loss of function in the lower extremity.

The consensus in the 2025 AAOS guideline supports the notion that the fasciotomy technique (single vs. dual

incision) is less important than achieving complete decompression of the affected compartments.⁴⁸ However, a recent retrospective cohort study on 190 patients with tibial plateau fractures and lower extremity fasciotomies revealed a significantly increased rate of surgical site infections using the dual-incision (41.3%) versus single-incision (18.1%) technique.⁴⁹ A novel post-fasciotomy classification system was recently proposed; however, there have not been any subsequent published validation studies to confirm clinical relevance and recommendations for adoption in surgical practice.⁵⁰ Post-fasciotomy, the compartments are irrigated with sterile saline and inspected for viability by Bovie-testing of muscle contraction. Nonviable muscle should be debrided. The intraoperative findings must be meticulously documented in the operative report at the time of the index surgery and for subsequent revision procedures.⁴⁷ The surgical incisions are left open after the procedure and covered by a nonconstrictive, absorbent wet sterile dressing (petrolatum-impregnated gauze, sterile 4×4 gauze, abdominal pads) or by application of negative pressure wound therapy for vacuum-assisted closure (VAC).⁵¹ Circumferential compressive dressings must be avoided due to the risk of an ongoing or recurring compartment syndrome. Scheduled “2nd look” procedures are performed within 24 to 48 hours until delayed wound closure is achieved. Recommended wound management options include VAC application, delayed primary skin closure by approximating the wound edges through a stapled vessel loop using a “Jacob’s ladder” (or shoelace) technique, or through delayed secondary wound closure by split-thickness skin grafting (Fig. 6). A recent retrospective cohort study on 10-years’ experience with fasciotomy closures revealed similar times to wound closure for VAC application (median 6 d) compared with conventional soft dressing application (median 6 d) or the shoelace closure technique (median 7 d).⁵¹

One technical trick that has worked well in the authors’ experience is to approximate the proximal and distal poles of the incision during 2nd look procedures, once the muscle swelling starts subsiding. The gradual marginal convergence is facilitated by approximating the skin edges with a pointed tenaculum at distance of about 5 cm to the respective wound poles. The skin between wound edge and tenaculum is then closed with interrupted 2-0 Nylon (or 2-0 Prolene) sutures in Allgöwer or Donati technique, at a distance of about 1 cm each. This gradual delayed closure is repeated in 5 cm increments as long as the wound edges adapt safely without tension. The technique allows to minimize the required skin grafting area by reducing the residual wound size, in some cases even allowing for a complete delayed primary closure without tension (Fig. 6C).

AAOS 2025 EVIDENCE-BASED GUIDELINES

The American Academy of Orthopaedic Surgeons (AAOS) published a revised edition of their evidence-

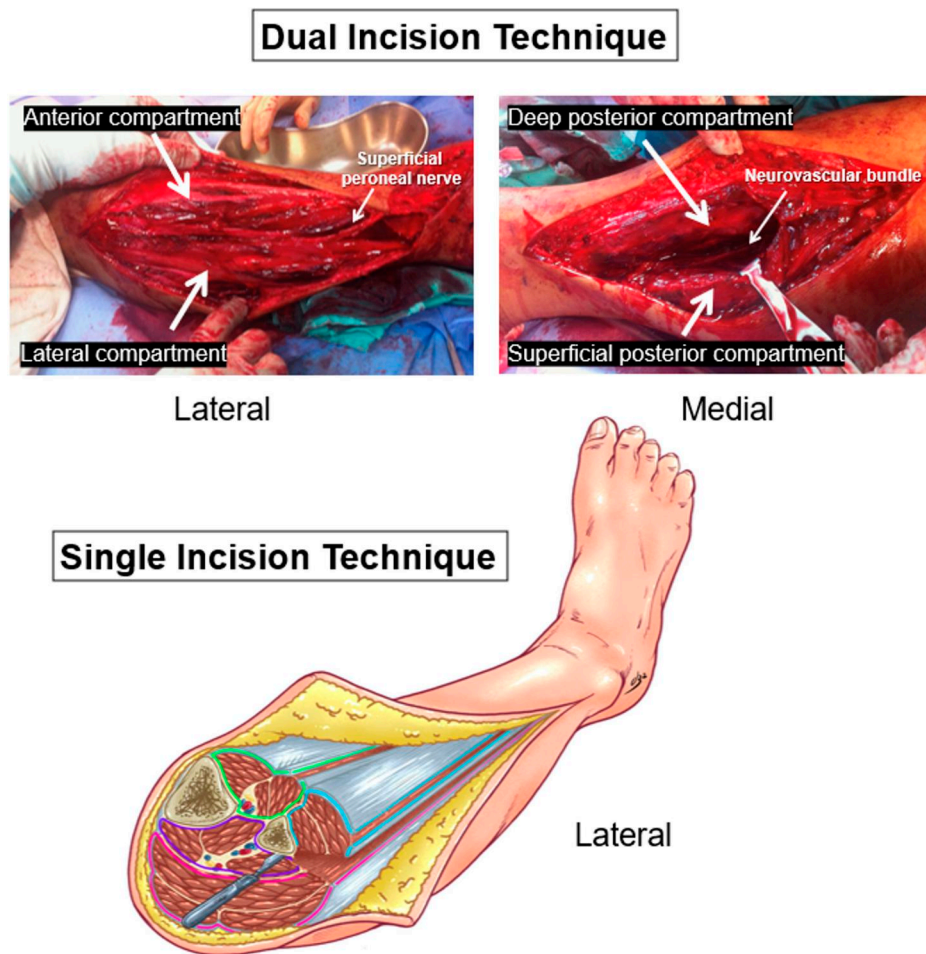


Figure 5. Complete four-compartment fasciotomy of the leg by conventional dual-incision technique (upper panel) or by a single-incision lateral approach (lower panel). See text for details and explanations.

based Clinical Practice Guideline on the management of acute compartment syndrome in 2025.⁴⁸ The strength of each clinical recommendation was graded based on the quality of evidence as strong, moderate, or limited in scenarios of low or conflicting evidence. In absence of reliable supporting evidence, the workgroup applied a consensus approach based on the members' clinical opinion and expertise. The recommendations from the 2025 AAOS Clinical Practice Guideline are summarized in Table 2.⁴⁸ The document is intended for orthopedic surgeons and other surgical providers who manage acute extremity compartment syndrome, with the goal of reducing the burden of a missed diagnosis and delayed treatment.⁴⁸

PEDIATRIC CONSIDERATIONS

Although the criteria for acute extremity compartment syndrome are not different between adult and pe-

diatric patients, establishing a diagnosis in young children can be very challenging, particularly in absence of trauma and an associated fracture.^{52–54} When in doubt, compartment pressure measurements should be obtained to establish a diagnosis, for example, in children with an altered level of consciousness.⁵² Interestingly, and divergent from the adult population, children have shown to have excellent outcomes even when the time window of acute injury to surgical fasciotomy is delayed beyond 24 hours.^{55–57}

SPECIAL SITUATIONS: CONTROVERSIES, PITFALLS, AND PEARLS

Controversy: Does Regional Anesthesia Mask an Evolving Compartment Syndrome?

An area of ongoing debate between orthopedic surgeons and anesthesia providers is the uncertainty of

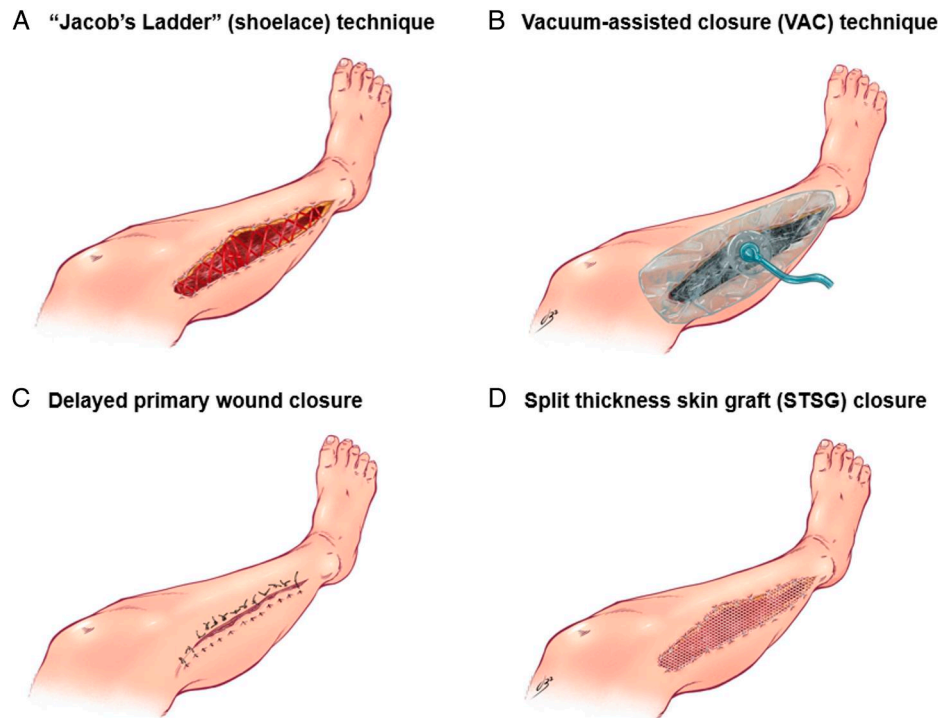


Figure 6. Wound closure modalities after four-compartment fasciotomy of the leg, as exemplified on the lateral incision. See text for details and explanations.

whether regional anesthesia techniques with peripheral nerve blocks for acute extremity fracture fixation may mask the postoperative symptoms of an evolving compartment syndrome.^{58–60} A systematic review on this controversial topic revealed a lack of consensus in the peer-reviewed literature regarding the safety of peripheral nerve blocks for long bone fractures and the underlying risk of obscuring the diagnosis of acute compartment syndrome.⁶¹ The authors attributed the absence of relevant guidance to the paucity of high-quality literature based on low incidence of acute compartment syndrome, and the level of evidence seemed to be limited mainly to anecdotal case reports.⁶¹ More recently, a working group by the Association of Anaesthetists of Great Britain published a pragmatic consensus guideline on “Regional analgesia for lower extremity trauma and the risk of acute compartment syndrome”.⁶² Table 3 summarizes the key recommendations from the consensus workgroup.

Pitfall: Well-Leg Compartment Syndrome

Well-leg compartment syndrome is a rare and strictly preventable iatrogenic complication that can occur when a patient is positioned in a lithotomy or hemilithotomy position for gynecologic, urological, and colorectal procedures,^{19,63} or for contralateral lower extremity fracture fixation on a traction table.^{20,64} The pathogenesis originates from prolonged knee flexion of the well-leg with pressure in the popliteal fossa leading to

temporary impaired arterial circulation, followed by ischemia/reperfusion-mediated acute lower extremity compartment syndrome.¹⁷ Key to recognition is a high level of suspicion in patients with acute lower extremity pain after procedures in hemi-/ or lithotomy position, requiring the consideration for immediate surgical four-compartment fasciotomies (Fig. 7). Preventive measures include avoidance of well-leg knee flexion beyond 90 degrees during initial patient positioning, adequate padding of the popliteal fossa, and intentional intraoperative repositioning of the well-leg with passive range of motion approximately every 30 minutes during surgery.^{19,20}

Pearl: Prophylactic Fasciotomy for Ischemia/Reperfusion Syndrome

Selected circumstances warrant a prophylactic fasciotomy when the occurrence of a subsequent delayed extremity compartment syndrome is predicted due to ensuing ischemia/reperfusion injuries.⁶⁵ This notion is exemplified by revascularization of an ischemic extremity due to the inherent risk of developing a subsequent compartment syndrome after restoring arterial blood flow to the extremity, resulting from complement-mediated ischemia/reperfusion injuries.^{10,65} As outlined under the technical surgical aspects above, it is imperative to perform a formal four-compartment release to ensure complete decompression and to avoid less invasive or incomplete fasciotomies.⁶⁶

TABLE 2. Summarized Key Recommendations From the American Academy of Orthopaedic Surgeons' Updated Clinical Practice Guideline on the Management of Acute Compartment Syndrome⁴⁸

Topic	Recommendations	Strength
1 Biomarkers	Myoglobinuria and serum troponin levels may assist in diagnosing acute lower extremity compartment syndrome. Serum biomarkers do not provide useful information to guide decision-making for fasciotomy in late-presentation or missed compartment syndrome.	Limited Consensus
2 Pressure monitoring	Intracompartmental pressure monitoring assists in diagnosing acute compartment syndrome. Use of repeated/continuous intracompartmental pressure monitoring to assist ruling out acute compartment syndrome (threshold for diagnosis: intracompartmental pressure over diastolic pressure < 30 mm Hg). Intracompartmental pressure monitoring does not provide useful information to guide decision-making for fasciotomy in adults with irreversible neuromuscular/vascular damage.	Moderate Moderate Consensus
3 Physical examination	Awake patients: limited evidence supports using serial examination findings to assist in diagnosing or ruling out acute compartment syndrome. Obtunded patients: repeated or continuous intracompartmental pressure measurements are recommended until acute compartment syndrome is diagnosed or ruled out.	Limited Consensus
4 Alternative methods of diagnosis	There are no reported alternative diagnostic modalities that provide useful information to guide decision-making for fasciotomy, other than intracompartmental pressure monitoring or clinical examination findings.	Consensus
5 Fasciotomy methods	The fasciotomy technique (single incision vs. dual incision) is less important than achieving complete decompression of all compartments in the affected extremity.	Consensus
6 Fasciotomy for late/missed compartment syndrome	Performing fasciotomy is not indicated in adult patients with evidence of irreversible intracompartmental (neuromuscular/vascular) damage. Fracture stabilization in these patients should utilize techniques that do not violate the compartment (eg, external fixation).	Consensus
7 Associated fracture	Operative fixation (external or internal) should be performed for initial stabilization of long bone fractures with associated acute compartment syndrome requiring fasciotomy.	Limited
8 Wound management	Negative pressure wound therapy may help fasciotomy wound healing with regard to reducing time to wound healing and reducing the need for skin grafting.	Limited
9 Pain management effects on diagnosis	Neuroaxial (regional) anesthesia may complicate the clinical diagnosis of acute compartment syndrome. If neuraxial anesthesia is administered, frequent physical examination and/or pressure monitoring should be performed.	Limited

Pitfall: Acute Exertional Compartment Syndrome

Acute exercise-induced (exertional) compartment syndrome can occur in absence of a trauma mechanism.⁶⁷ The diagnosis should be suspected in any patient presenting with insidious muscular pain out of proportion, independent of the timing and intensity of the preceding exertional activity.^{67,68} The diagnostic work-up and surgical decision-making are equivalent to patients with acute traumatic compartment syndrome, as described above. The critical difference is that patients without an underlying trauma mechanism are typically seen by less experienced providers in the emergency room who may not consider acute compartment syndrome in their differential diagnosis. Thus, missed exertional compartment syndrome represents one of the most frequent root causes of litigation.^{36,40} The risk of a nondefensible claim is highest in the absence of meticulous documentation of the differential diagnosis, clinical presentation, and documented rationale for the individual provider's thought process when a decision is made not to proceed with surgical fasciotomies.^{36,68} The published average time to claim closure has been reported around 5.5 years, which imposes a significant medicolegal and mental burden on the involved physicians.⁴⁰ Evidence of poor physician-patient communication was shown to represent the main root cause of verdicts against physicians with resulting indemnity payments.⁴⁰

Pitfall: The Incomplete Fasciotomy

A classic pitfall for less experienced surgeons who may not be as familiar with the calf anatomy pertains to a limited "two-compartment fasciotomy" of the leg by accidental omission of releasing the lateral and deep posterior compartments (Fig. 4). The mistake occurs when the lateral and deep posterior compartments are not addressed under the erroneous assumption that the fasciotomies of the anterior and superficial posterior compartments would constitute a full release. This oversight may eventually lead to two missed "dead" compartments with associated loss of function in the lower extremity. Adverse outcomes with increased mortality and delayed extremity amputation rates have also been reported for incomplete fasciotomies through limited fascial incisions without a full release of the respective muscle compartments.^{23,43}

Pearl: Standard Four-Compartment Fasciotomy (Dual-Incision Technique)

Lateral Approach (Anterior and Lateral Compartments)

1. A generous longitudinal skin incision is made between the fibular head and the anterior bony crest of the proximal tibia. The incision extends the full length of

TABLE 3. Summarized Recommendations From the Association of Anaesthetists of Great Britain “Working Party” Guidelines on the Use of Regional Anesthesia in Patients at Risk of Lower Extremity Compartment Syndrome⁶²

Patients at risk of acute compartment syndrome for lower leg trauma should be identified on admission to hospital or at the time of surgery. All patients who have suffered trauma or who have undergone surgery should be offered effective analgesia.
The use of neuraxial or peripheral regional techniques that result in dense blocks of long duration, which significantly exceed the duration of surgery, should be avoided.
Single-shot or continuous peripheral nerve blocks using low-dose local anesthetics without adjuncts are not associated with delays in diagnosis of acute lower extremity compartment syndrome.
Awake patients at risk of acute compartment syndrome should be given a full explanation of the choice of analgesic techniques and should provide documented consent to the chosen analgesic modality, if possible.
Post-injury and postoperative surveillance should identify the signs and symptoms of acute extremity compartment syndrome. The use of objective scoring charts is recommended.
The equipment necessary to measure intracompartmental pressure should be available and staff should be trained in its use, with standard operating procedures available, including the urgent steps to be taken if pressure measurements are abnormal.
Neither the surgeon nor the anesthetist has the mutual right to veto a treatment modality recommended by the other specialty. Ideally, consensus should be achieved. If consensus is not achievable, the anesthetist, as the expert on pain relief, will have the decisive authority over the recommended analgesic modality.
Given the lack of reliable, published data on the safety and efficacy of analgesia in patients at risk of acute compartment syndrome, the “Working Party” recommends that studies that address the use of low-dose regional analgesia, spinal opioid analgesia, and wound infusion with local anesthetics for patients undergoing surgery for lower extremity injuries should be conducted as a matter of urgency.

the leg and ends a few centimeters above the lateral malleolus.

- After skin incision, the intermuscular septum is identified as a thick fascial boundary and incised to divide the anterior and lateral compartments. A short incision is made with a #15 blade proximally to release the anterior compartment along the length of the skin incision with blunt scissors (eg, Metzenbaum scissors). During the release of the anterior compartment, the anterior tibial nerve, artery, vein are located between tibialis anterior and extensor hallucis longus. The anterior neurovascular bundle is typically not at risk as long as the dissection is strictly restricted to the fascial layer.
- The lateral compartment is released in analogous manner. Care has to be taken when sliding the scissors down the fascia over the lateral compartment to avoid injury to the superficial peroneal nerve, which should be identified and protected (Fig. 5).

Medial Approach (Superficial and Deep Posterior Compartments)

- A generous longitudinal skin incision is made about 2 cm posterior to the palpable tibial border. Care is taken to avoid injury to the saphenous vein or nerve. In analogy to the lateral approach, the medial incision should be taken down the length of the leg and end proximal to the medial malleolus. After skin incision, the fascia over the gastrocnemius-soleus complex is opened with blunt scissors to release the superficial posterior compartment.
- The gastrocnemius-soleus complex is retracted posteriorly with a blunt retractor (eg, “Army-Navy”). This retraction will expose the deep posterior compartment in the distal portion of the approach. The posterior neurovascular bundle (tibial nerve, artery, vein) is typically visible through the thinner fascia over this compartment. Care

should be taken to avoid injury to the bundle while performing a complete release of the deep posterior compartment using blunt scissors (Fig. 5).

- Once all four compartments have been released, it is imperative to document the muscle color (pink, gray, dusky, necrotic) and its viability by Bovie cautery testing. Necrotic tissue must be debrided, if present. Full compartment release is assured by digital palpation to prevent incomplete fasciotomies from residual fascial elements.
- Application of the postoperative wound dressing is performed in analogy to the previously outlined options (Fig. 6).

Pearl: Video-Based Education Improves Surgical Competency

A recent experimental study was designed to investigate the effect of a just-in-time video-based education, termed the “Surgical Technical Assistance Tool” (STAT). The intent of the brief educational refresher was to reduce the occurrence of preventable surgical complications, such as incomplete fasciotomies.⁶⁹ The anatomic cadaver study assessed 44 surgeons for their competency in performing standardized upper and lower extremity fasciotomies. The study design was stratified by surgeons who were trained by STAT before the respective procedures (n = 22) versus surgeons in the control group (n = 22) without educational support.⁶⁹ The results demonstrated that the surgeons in the STAT group had significantly superior individual procedure scores, reflected by the number of adequately decompressed compartments, compared with the surgeons in the control group (Fig. 8).⁶⁹

Pitfall: Missed Upper Extremity Compartment Syndrome

Acute compartment syndrome is more common in the lower than in the upper extremities, which may pro-

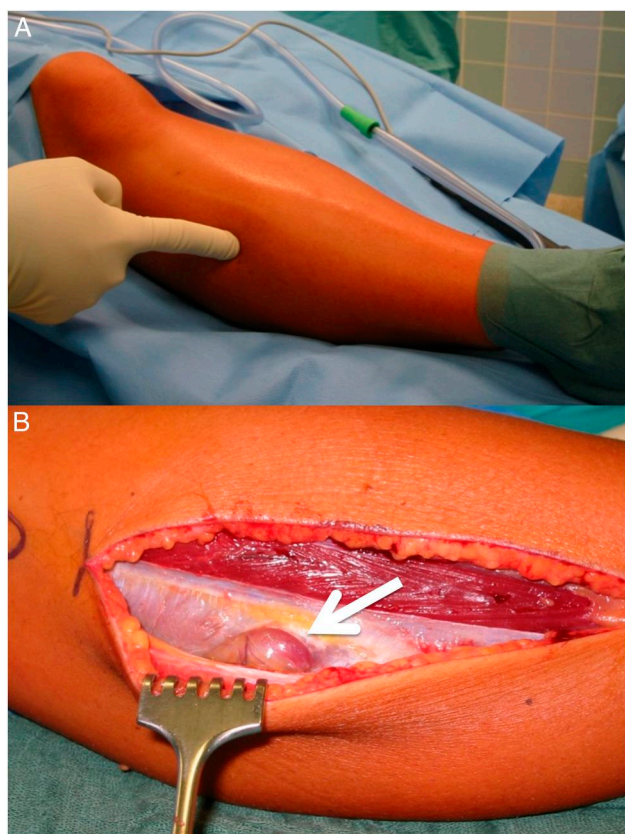


Figure 7. Well-leg compartment syndrome in a 25-year-old female patient who underwent a 90-minute gynecologic procedure in lithotomy position. The patient developed pain out of proportion in both legs overnight on the nursing floor, requiring orthopedic consultation and emergent bilateral four-compartment fasciotomies. The acute muscle bulging is seen on incision of the lateral compartment (arrow).

vide the reason that a diagnosis of upper extremity compartment syndrome is frequently missed, likely because “we just don’t think about it.” Figure 3 exemplifies a missed postoperative compartment syndrome after surgical plate fixation of a both-bone forearm fracture in a young 20-year-old patient. The late clinical presentation was recognized on postoperative day 1, when the patient was unable to extend his wrist due to a posterior interosseus nerve (PIN) palsy from compression of the deep motor branch of the radial nerve. The patient was emergently taken back to the operating room for a complete fascial release of the forearm compartments through the two pre-existing surgical incisions. The wounds were closed by secondary intention on postoperative day 4 and the PIN palsy had resolved by the 3-month follow-up visit. This case exemplifies the imperative for a high level of clinical suspicion for upper extremity compartment syndrome in presence of an associated forearm fracture.^{70,71}

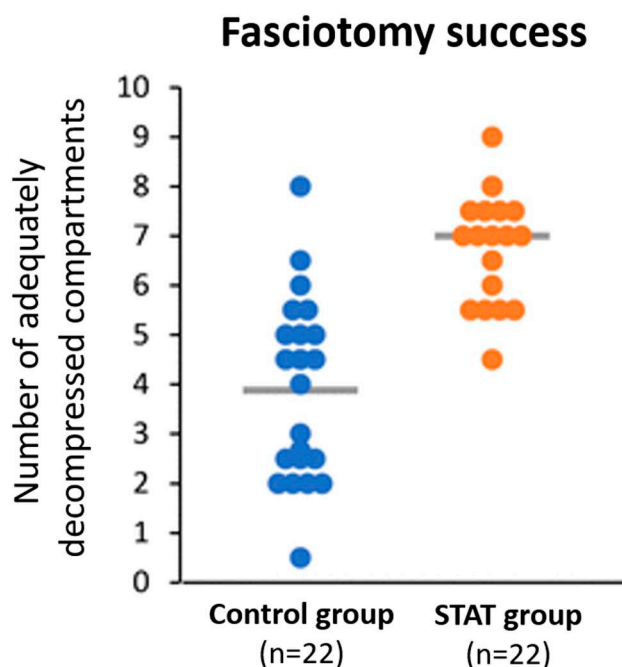


Figure 8. A video-based, just-in-time educational refresher tool increases surgeons' competency in anatomic, procedural, and technical scores for upper and lower extremity compartment fasciotomies. Volunteer surgeons were stratified into STAT ("Surgical Technical Assistance Tool") pre-procedural video training (n=22) versus no educational support (n=22) for standardized upper and lower extremity cadaveric fasciotomies. Reproduced with permission through the Creative Commons Attribution Non-Commercial License (CC BY-NC) by Fuller et al.⁶⁹

Pearl: Forearm Fasciotomy Technique (Volar Approach)

There are numerous variations described for forearm fasciotomies, and most surgeons utilize their most familiar approach to address the patient's specific injury pattern. The surgical technique below summarizes the extensile curvilinear volar approach, which is preferred by the authors in general (Fig. 3D). This approach provides exposure for decompression of the volar compartment, the mobile wad, and release of the carpal tunnel.

1. A curvilinear incision is made, as shown in Figure 3D. Proximally, the incision begins just medial to the biceps tendon, curves laterally across the antecubital fossa to the mobile wad and then continues distally along the volar forearm. This approach provides exposure for decompression of the volar compartment, permits release of the mobile wad, and allows extension across the carpal tunnel.
2. The lacertus fibrosus is released, which spans medially to the biceps tendon. Blunt tip scissors are used for dissection to avoid injury to the median nerve and brachial artery (eg, Metzenbaum scissors).

3. The fascia over the pronator teres is released to decompress the palmaris longus (if present), flexor carpi ulnaris, and the mobile wad laterally.
4. As the incision extends distally, the fascia is released over the residual superficial flexor compartment, including flexor carpi radialis and flexor digitorum superficialis.
5. The deep volar compartment is released by opening the deep antebrachial fascia to expose flexor digitorum profundus and flexor pollicis longus. A complete decompression of both superficial and deep volar compartments is confirmed.
6. In the distal portion of the incision, surgical variations are described by extending the incision more ulnar to release Guyon's canal. We prefer extending the incision more radial over the carpal tunnel, as shown in Figure 3D.
7. The wrist crease is crossed obliquely or in a gentle zig-zag incision, to minimize the risk of a postoperative scar contracture. The incision is continued in line with the ulnar border of the long finger to avoid injury to the recurrent motor branch of the median nerve.
8. The palmar fascia is incised along the longitudinal fibers, followed by the transverse fibers of the carpal ligament. The median nerve is visualized and protected throughout the surgical release, recognizing that the recurrent motor branch has different anatomic variants. Placing a blunt elevator deep to the transverse carpal ligament during the dissection provides protection to the median nerve and the underlying flexor tendons.
9. After release, the median nerve and underlying flexor tendons are visualized to confirm complete decompression of the carpal tunnel.
10. All released compartments are visualized and assessed digitally to ensure absence of residual fascial bridges. The color and viability of the forearm muscles are inspected and tested by cautery. Any necrotic muscle is debrided.
11. The dorsal compartment and mobile wad are reassessed, subsequent to the volar release. In general, these compartments become substantially softer after the volar decompression and will not require a separate fasciotomy through an additional posterior incision. However, if either compartment remains tense and of clinical concern, a separate dorsal compartment release should be performed.
12. Meticulous documentation of the intraoperative findings is imperative.
13. Application of the postoperative wound dressing is performed in analogy to the previously outlined options (Fig. 6).

Pearl: Contraindication for Surgical Fasciotomies

The presence of “dead compartments” secondary to crush injuries, for example, after prolonged extrication of earthquake victims, represents one of the rare contraindications for surgical fasciotomies. In addition to the systemic burden of rhabdomyolysis and crush syndrome,

adverse outcomes have been reported from unnecessary fasciotomies.^{72–75} This is due to subsequent contamination and infection of open devitalized muscle compartments, leading to preventable infections with delayed extremity amputations, sepsis, multiorgan failure, and death.^{72–75} The 2025 AAOS guideline (Table 2) recommends against decompressive fasciotomies in patients with late/missed extremity compartment syndrome, due to the unjustified risk of soft tissue infections with subsequent adverse outcomes. In addition, the required extensive surgical débridement of all dead compartments will result in a nonviable “peg leg” with worse predicted outcomes than a primary below-the-knee amputation.⁴⁴ Meticulous documentation is warranted for any scenario where a surgeon deliberately chooses to deviate from surgical fasciotomies, ideally with a cross-reference to the 2025 AAOS Clinical Practice Guideline.⁴⁸

CONCLUSIONS AND FUTURE AREAS OF RESEARCH

In summary, acute extremity compartment syndrome remains a clinical diagnosis, and early surgical fasciotomy is the only effective treatment. The diagnosis requires a high level of suspicion in any patient presenting with extremity pain out of proportion, independent of the underlying trauma mechanism, also in the absence of any evident etiology. It is imperative to keep in mind that this diagnosis is not always dichotomous but rather a spectrum of signs and symptoms that evolve over time. The modern interpretation of the historic 6 clinical “P’s” should be provocatively modified to “Pain! Pain! Pain! Pain! Pain! Pain!” (out of proportion). Pressure measurements, either as single-point assessment or by continuous monitoring, are considered an adjunct in patients with limited or equivocal clinical examination. The consensus threshold for consideration of a surgical fasciotomy is represented by an intracompartmental pressure within 30 mm Hg of the diastolic blood pressure. Pitfalls include late/missed diagnosis and incomplete fasciotomies with associated adverse outcomes and increased mortality. There are multiple promising avenues of ongoing experimental research. A recently published animal study using an extremity compartment syndrome model in Sprague-Dawley rats revealed that low-intensity pulsed ultrasound (LIPUS) alleviates the extent of muscle injury by suppressing oxidative stress and lipid peroxidation through attenuation of ferroptosis expression in injured muscles.⁷⁶ In absence of a “bench-to-bedside” extrapolation from experimental models, the current pertinent literature still does not offer a diagnostic standard for acute extremity compartment syndrome, and the treatment by surgical fasciotomy is widely considered a surrogate marker for the diagnosis. In addition to emphasizing the importance of the clinical examination, future education and research should focus on identifying accurate objective diagnostic tools. Serum biomarkers and combined laboratory and physiologic scores may help establish the diagnosis at different stages of disease evolution and guide more timely appropriate treatment.

AUTHORSHIP

P.F.S. drafted the first version of the manuscript. B.L.B. and N.Z. contributed to revisions and helped finalize the paper for submission. B.L.B. contributed the graphic artwork in the figures. All authors read and approved the final version of the manuscript.

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DISCLOSURE

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